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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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THE JOURNAL
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THE ROYAL ASTRONOMICAL SOCIETY
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Vol. XXXV, No. 9 NOVEMBER, 1941 WHOLE No. 308

THE DEPRESSION OF LUNAR CRATERS

By R. A. McINTOSH

THE question of the depth to which a meteorite might penetrate below the surface of the moon before exploding to form a crater, according to A. C. Gifford's theory[1] of the meteoric origin of the lunar features, must remain a debatable one. Gifford himself has indicated the possibility of the meteorite enduring for a tenth of a second after impact and thus, in the case of the faster objects, attaining a depth of two miles. Dr. L. J. Spencer[2] believes that a meteorite would not penetrate so deeply, while others appear to favour even greater depths. The amount of penetration, however, is not an essential part of the theory, and therefore has escaped attention.

Assuming for the moment that the lunar craters do arise from meteoritic explosions, the depression of their floors below the surrounding surface should reveal the depth of penetration of the original crater-forming meteorite, since the explosion should drive the ejected material radially outward and upward and have little effect (except perhaps of compression or consolidation) on the material lying below the point of explosion.

Using the data compiled by T. L. MacDonald[3] in his recent statistical studies of the lunar craters, I have calculated the depressions of the floors of the craters below the surrounding surface. The results, tabulated in Tables I and II, follow MacDonald's classification of the lunar formations into two groups: Craters (objects with central peaks), and Walled Plains (those

[1]This JOURNAL, vol. 25, p. 70, Feb 1931.
[2]*Nature*, vol. 139, p. 655, 1937.
[3]*Journal of Brit. Ast. Assoc.*, vol. 41, p. 175, Feb. 1931.

without this feature). In a number of cases measures given in the original data were regarded as doubtful, and while these have been used in the present paper (being printed in parentheses in the tables), a distinction has always been made between them and the more reliable measures.

TABLE I.—DEPRESSION OF CRATER FLOORS

Object	Depression	Diameter	Object	Depression	Diameter
	metres	km.		metres	km.
Langrenus	3250	130	Alpetragius	1750	42
Theophilus	3250	103	Mairan	1350	40
Arzachel	(1500)	100	Manilius	1450	40
Copernicus	2900	90	Harpalus	(1450)	39
Piccolomini	(2500)	90	Autolycus	1450	38
Cyrillus	2100	89	Timocharis	1100	36
Hainzel	2000	88	Picard	1200	34
Tycho	2250	87	Halley	(1200)	33
Geminus	2400	86	Mason	(800)	33
Metius	(1350)	80	Mädler	1200	32
Stevinus	1400	75	Euler	1350	30
Werner	2650	72	Lambert	1350	30
Santbech	(2300)	70	Schiaparelli	(1500	26
Taruntius	500	70	Delisle	1350	25
Macrobius	(1650)	66	Flamsteed	(1450)	25
Bullialdus	2000	60	Clavius d	1950	24
Eratosthenes	2150	60	Mösting	(1500)	23
Scoresby	2100	58	Dawes	(650)	21
Aristillus	1800	56	Triesnecker	(950)	21
Jacobi	2050	54	König	(1150)	20
Plinius	(1650)	51	Peirce	1250	20
Clavius b	1550	48	Bullialdus B	(750)	19
Reinhold	2050	47	Pytheas	(650)	19
Landsberg	1450	45	Leverrier	1450	18
Agrippa	(1150)	44	Cassini A	(1400)	17
Abenezra	2000	42	Posidonius A	(550)	12

It is seen from the tables that the greatest measured depressions, 3,250 metres (10,600 feet), occur in the craters Langrenus and Theophilus and the walled plain Clavius. These are roughly equivalent to Gifford's estimate of two miles, but the average depressions of the floors of these objects are necessarily much less (although the data excludes objects less than 10 km. in diameter), being as follows:—

	Best measures	All measures
Craters.....	1760 m. (5770 ft.)	1600 m. (5250 ft.)
Walled Plains.....	1084 m. (3560 ft.)	1110 m. (3640 ft.)

The distribution of the frequencies of the depressions is shown by the histogram in Figure 1. It is evident that the craters generally

TABLE II.—DEPRESSIONS IN WALLED PLAINS

Object	Depression	Diameter	Object	Depression	Diameter
	metres	km.		metres	km.
Clavius	3250	230	Hansteen	(100)	50
Schickard	(650)	215	Billy	350	50
Schiller	(1200)	180	Segner	(500)	48
Ptolemaeus	(600)	165	Azophi	(1950)	48
Walter	(950)	150	Beaumont	750	48
Longomontanus	(2650)	145	Agatharchides	400	46
Stöflerus	(2300)	145	Parry	(400)	44
Vendelinus	(1050)	135	Brieslak	(1100)	42
Cleomedes	(1350)	128	Davy	(300)	37
Marolycus	2600	115	Liebig	550	35
Phocylides	(350)	114	Sömmering	(400)	35
Posidonius	1050	100	Cichus	400	33
Plato	800	95	Sabine	(450)	30
Aristoteles	(1950)	90	Theatetus	1500	30
Orontius	(1300)	90	Calippus	550	29
Atlas	1050	85	Bessel	800	20
Barocius	400	82	Diophantus	1600	20
Archimedes	400	80	Milichius	(350)	17
Cuvier	(2050)	80	Marius A	(1600)	16
Licetus	(2050)	78	Birt (N)	1050	14
Casatus	1450	72	Messier A	1400	14
Eudoxus	700	72	Picard d	1700	13
Mersenius	1100	69	Euler B	(600)	10
Faraday	(2100)	64			

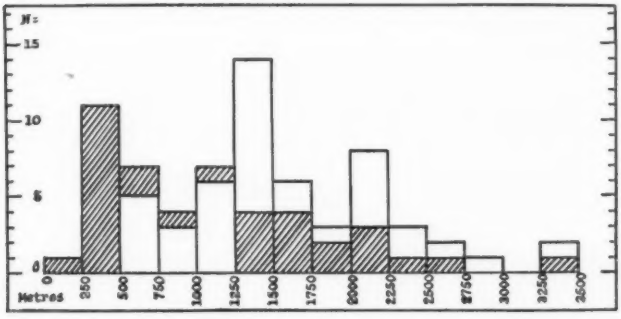


Fig. 1.—Histogram showing frequency distribution of depressions. Craters, in white blocks; walled plains, in shaded blocks.

are more depressed than the walled plains. This may arise from the latter suffering partial filling subsequent to the creation of

the crater pit. The minor fluctuations of the frequency curves have no significance, owing to the small number of measures available.

It occurred to me, while preparing material for a lecture, that if the depression of a crater floor could be shown to bear any relation to the diameter of the crater a strong argument in favour

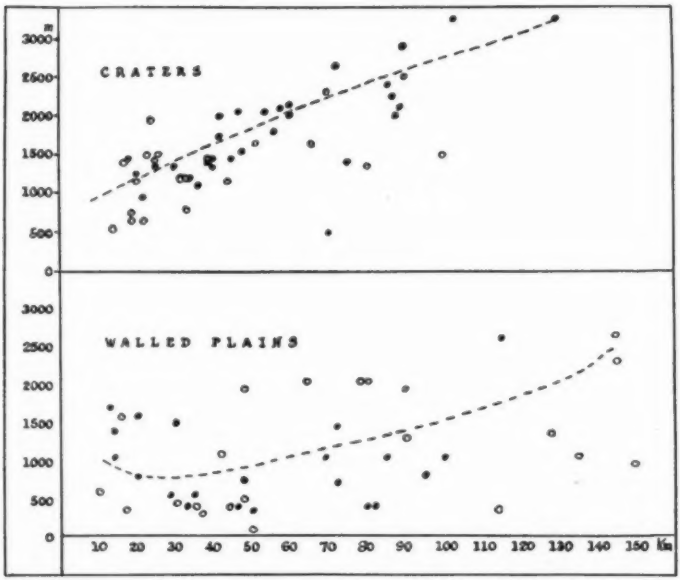


Fig. 2.—Showing the relation between depressions and diameters of craters and of walled plains.

of the meteoric theory would be established. The investigation accordingly was made, the result being shown graphically in Figure 2.

Pearson correlation co-efficients were determined as follows:—

Craters.....r = +0.75±0.06 (Best measures)
r = +0.76±0.05 (All measures)

Walled Plains.....r = +0.63±0.08 (Best measures)
r = +0.36±0.09 (All measures)

Close correlations between the depressions and diameters of craters and a reasonably close correlation in the case of the best measures of walled plains are therefore established, notwithstanding the fact that many of these latter show obvious traces of partial flooding or filling subsequent to their formation.

It is difficult to see how such a relation can be explained by the volcanic theory. The vulcanologists might suggest that the more deep-seated the explosion the greater the amount of material ejected, but if the explosion were volcanic why should it invariably leave behind it only sufficient material in the undestroyed portion of the cone (the crater walls) to fill the depression formed by the explosion?

Private Observatory,
1 Melford Street,
Auckland W.1, N.Z.,
1941, July 14.

BEZA'S VERSES ON TYCHO'S NOVA

By Thomas L. MacDonald

THE note by W. Kenneth Angus in this Journal, 1941, July-August, may be more interesting still if something is said about the author of the verses there reproduced. Theodore de Besze or Beze (usually referred to in the Latin form as Theodorus Beza) is one of the more prominent figures of the Calvinist church. He was born in 1519 at Vezelay in Burgundy and died in 1605 in Geneva. In his early years he was most influenced by Melchior Wolmar who was also Calvin's tutor. A serious illness in 1548 proved to be the occasion of his conversion to protestantism, to which he had no doubt been trending under these influences. He became a professor of Greek in Lausanne, Switzerland (1549-58), then spent the rest of his life in Geneva. On Calvin's death in 1564 he was his obvious successor. In 1590 and again in 1602 he encouraged the townsmen to withstand war and siege: his last words are supposed to have been, "Is the city in full safety?"

It is needless to stress the detestation in which his views were held by the followers of the old church: in his historical writings, Riccioli (the Jesuit astronomer who gave the names we still use to many of the craters on the Moon) includes him in his catalogue of heresiarchs: his key word for Beza is "obscœnissimus", which needs no translation: Riccioli also outlines some of his particular heresies, which need not concern us here.

As a young man Beza published a collection of Latin verses in the style of Ovid and Tibullus (*Poemata Juvenilia*, 1548). His later writings go further to explain why a translation from his Latin verse should appear in a London pamphlet of 1578. In 1565 he edited the Greek New Testament with a translation into Latin which he made himself alongside of the Vulgate rendering. This important work was dedicated to Elizabeth, Queen of England. It is not necessary to go far into the history of the time to realize how Queen Elizabeth figured in the minds of protestant reformers in Holland and Switzer-

land: and the *Confession* and *Ecclesiastical History** of Beza, like the sermons of Calvin, were pretty well known in the England of the time.

In 1580 the *Icones* were published. This was a collection of portraits of prominent reformers, of great value to the historian, accompanied by notes on each engraving. And this book is dedicated to James VI of Scotland, later of course James I of Britain, then fourteen years of age. It has been suggested that the Emblemata which follow the portraits were intended to entertain the boy king: they have nothing to do with the rest of the book: each of them is a small engraving with some lines of Latin verse below. The book was translated into French by Simon Goulard, in the following year.

It is not surprising, either, that Beza should have written on the New Star of Tycho. The references in Dreyer's life of Tycho are sufficient to show what a sensation it was in its time. And it is natural that the reformer should treat the Nova as a recurrence of the Star of Bethlehem, coming to declare "that Christ returns *agayne* in might" as a result of the reformation! (John Knox died in 1572 and in 1571 Beza had presided over the Synod of Rochelle.) The psychological background of the verses is clear. It might perhaps be added that there was keen interest in protestant circles, in the rapid development of astronomy: recent studies have shown the significance of the Elizabethan astrologer-astronomers like Digges and Dee: and one of Beza's own *Icones* is of Sebastian Munsterus of Ingleheim who was professor of Hebrew, Physics, and Geography in Basle, Switzerland, while Beza was at Lausanne: the writings of Münster include *Horologiographica* (on dialling), *Cosmographia Universalis*, and works on elementary mathematics and planetary motions.

*Although in *Encyc. Brit.*, 14th ed., v. 3, p. 490, it is stated that Beza was not the author of this work published in 1580.

Newcastle upon Tyne, England,
September, 1941.

AURORAL DISPLAY AND GEOMAGNETIC STORM OF SEPTEMBER 18-19, 1941

By A. G. McNish (in *Science*, October 31, 1941)

ONE of the greatest auroral displays ever observed in the central Atlantic and mid-central portions of the United States occurred on the night of September 18-19. Spectacular displays continued from twilight until just before dawn, and were observed as far south as Florida and southern California. The auroral activity accompanied one of the most violent magnetic storms of the present sun-spot cycle, nearly equaling in intensity and exceeding in duration the great storm of Easter Sunday, March 24, 1940. Serious interference with radio and wire communications over long distances was experienced, as well as noticeable effects on electric power-transmission lines.

This geomagnetic storm is generally ascribed to clouds of electrified particles projected from the sun in the region of an extraordinarily active sun-spot group which had crossed the solar meridian shortly before the onset of the disturbance. The progress of this sun-spot group across the sun had been followed by a number of observers for several days. Just at the time of crossing the solar meridian an increase in activity in the group was noted. Since such active groups frequently give rise to geomagnetic disturbances, H. W. Wells, of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, had warned numerous radio operators to be on the lookout for disturbances in radio transmission-conditions, so that occurrence of the magnetic storm was not entirely unexpected by scientists, although its great intensity and the extent of the auroral manifestations were not anticipated.

The storm began at 11 p.m., Eastern Standard Time, on September 17, and attained maxima of activity between 1 and 3 p.m., and between 7 and 10 p.m. on September 18. During both of these periods of intense activity, effects were noted on the 230-kilovolt interconnecting line tying the power-system of Washington, D.C., into the hydroelectric developments along the Susquehanna River in Pennsylvania, approximately 100 miles to the north. The second period of disturbance also was the time of maximum auroral activity. Changes

in horizontal magnetic intensity at the U.S. Coast and Geodetic Survey Observatory at Cheltenham, Maryland, amounted to over 2,500 gammas, which is approximately 15 per cent. of the normal value at that station, the greatest change ever recorded there.

During the second active interval, which occurred during the hours of darkness, bundles of auroral rays were directed downward through the high atmosphere over the eastern section of the United States. These rays, because of the electrical nature of the particles causing them, took the direction of the earth's magnetic field and consequently assumed roughly parallel directions and approached the earth's surface in alignment with the magnetic dip which at Washington, D.C., is nearly 20° from the vertical. To observers viewing these rays they appeared to be parallel, and like all parallel lines, appeared to converge in the distance. For this reason many persons noted a spectacular coronal display of the aurora borealis where the rays appeared to converge slightly south of the true zenith toward a point known as the magnetic zenith.

Throughout the night the auroral activity exhibited various forms. At times extensive quiescent auroral arcs crossed the sky in a roughly east-west direction. These changed into draperies, rays and curtains, as the various auroral forms are picturesquely described. In the extreme northern part of the country and in southern Canada brilliant colours in the aurora were reported by many observers, although throughout the greater portion of the United States the auroral forms were with little colour although occasional casts of red and green could be detected. Auroral displays were observed in the northern part of the United States on the nights of September 17-18 and 19-20 also, but of greatly diminished intensity.

No complete theory of geomagnetic storms and aurorae has been developed. The most generally accepted theory attributes both to the injection into the earth's atmosphere of high-velocity electrified particles projected from active regions on the sun. These particles, entering the tenuous layers of the upper atmosphere, excite the molecules and atoms of the air and thus give rise to the auroral light in very much the same manner as glows are produced in neon signs. The energies of these particles also ionize the atmospheric gases and render them electrically conducting so that large electric currents

flow through the upper atmosphere. These produce the magnetic effects recorded by the magnetic instruments and also induce electric currents in power and telegraphic lines. This electrification of the upper atmosphere is irregular in formation and consequently destroys the reflecting properties of the smooth but lesser conducting layers normally present which are responsible for reflection back to earth of radio waves traversing long distances. During the magnetic storm of September 18-19 electric currents flowing in the earth's atmosphere probably attained values of several million amperes.

Magnetic storms of intensity comparable with the recent one are extremely rare, occurring as a rule only once or twice during each sun-spot cycle. Since the present sun-spot cycle is now well on the decline, it is extremely unlikely that so great a magnetic storm accompanied by a spectacular auroral display will occur again for a considerable number of years.

Department of Terrestrial Magnetism,
Carnegie Institute of Washington.

WHAT TO DO ABOUT ASTROLOGY

By A.G.I. in "Our Point of View" in *Scientific American*

ASTRONOMICAL circles—particularly the seventy local groups and clubs of amateur astronomers on this continent—have recently been greatly exercised because a Hollywood motion picture producer is preparing to release a series of twelve films on astrology. They are fighting it.

This, we believe, will be the first large-scale incursion of astrology into the motion picture audience. Astrology's following already is immense, running, we are told, into the millions.

We have added our protests to those already made, simply writing to Mr. Will Hays, motion picture "czar" at Hollywood, that we wish to go on record as stating that scientists stand solidly against the pseudo-science of astrology—which, of course, is a fact.

It would serve little purpose here to try to refute astrology, since we can assume that our readers already oppose it—though each time we have mentioned it in this magazine without much respect, we have, it is true, received letters of protest, but never more than a trifling few. The question is, rather, what can *Scientific American* readers do to fight astrology in other circles where it is accepted?

For years we have given this matter much thought, but no real answer has appeared. It is easy to refute astrology—for those who already regard it as a pseudo-science; but it is not easy to refute it for those who want to believe in it. In fact we feel that, in the main, no direct attack on astrology is likely at all to have more than a limited effect until the general standard of education has been raised—a long, slow process. When that has been done there will automatically be little need to refute astrology.

Two notable attempts in the direction of refutation have been made in recent years, one a rather intellectual paper by Dr. Bart J. Bok and Margaret W. Mayall, astronomers at the Harvard College Observatory, and the other a rather practical if not hard-boiled approach made a year or so ago by our contemporary, *Good Housekeeping*, which probably reaches far more who believe in astrology than does *Scientific American*. *Good Housekeeping* put the

astrologers in a truly awful predicament—and then did nothing to save their faces. It offered to place four astrologers, selected by other astrologers, in separate rooms where they were each to cast the horoscopes of two persons to be selected by the editors. It also agreed in advance to publish the findings, regardless of their outcome. That challenge was not accepted—proving that the astrologers are not fools at all, whatever else they may be.

It is probably not correct, however, and it certainly is not good psychology, if one wishes to shake their beliefs, to label the astrologers fakes and frauds, as some have. Individual frauds there undoubtedly have been, and are, within astrological circles, but in the main the astrologers are honest people who sincerely believe what they believe, and are a bit hurt, in fact, because the scientists treat them somewhat roughly. They are also puzzled because science seems so stupidly blind to the obvious truths they claim to possess. Bigotry and intolerance, this attitude from our side appears to them—and, to tell the truth, some of us really have been bigoted and perhaps intolerant toward astrology. We need to cultivate more patience. Most of these people who accept astrology have had no background in the scientific world, and therefore have no way of seeing the difference between science and pseudo-science; to them, each looks about alike. Moreover, the fact is, and we should admit it, that, even within our world of science, there is not and never has been any way to distinguish positively between truth and error—all such things must be considered as relative.

If one merely wishes to have some fun, and to start a believer in astrology off on an hour's sputtering and raving, just call astrology a fraud and a fake. But if the desire is genuinely to alter his state of mind, that sort of approach is only certain to fix it. Arguing with the typical astrologer is not likely to prove very satisfying. You find that his arguments are not so much rational as emotional. And he is shifty—though we do not necessarily mean dishonest. Once, when a group of amateur astronomers in one of our larger cities was preparing to put on a public debate for and against astrology, we warned its officials that they would not get very far. They wrote afterward thus: "Reasoning with the astrologers proved to be just like punching a feather pillow—you sock it in one place and it bobs up

in another. You had them figured out to a tee, and everything you promised for us came true. They haggled about definitions. So we got nowhere."

Haggled about definitions—here is the chief rub, but it's something which few except trained logicians understand as sharply as they should. In any argument, of any kind, unless the two sides accept *at least the premises in common*, there has been no real meeting of minds—no real argument. The astrologers argue from a different set of premises than do the astronomers. Probably there is, therefore, little that can be done about it, until we succeed in reaching the general standard of education mentioned a few paragraphs back.

The fact is that, on the whole, there probably is little that can be done about astrology; probably we on the scientific side haven't yet come fully to realize this fact. We tend to think that, in some manner or other, a way can be discovered, if we try hard, to knock the astrology out of those who believe in it. It appears that this, like astrology itself, is mainly a delusion. It probably will take centuries, millenia, to rationalize humanity to the extent necessary to do away with astrology and equally unscientific beliefs.

Nevertheless, all protests against the aforementioned films, sent to Mr. Will Hays, Hollywood, California, should carry due weight in the immediate circumstances and perhaps help to prevent further exploitation of the gullible.

THIRTIETH ANNUAL MEETING OF THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS

By D. W. Rosebrugh, Secretary

THIS was held at Harvard Observatory on October 10-11, 1941, through invitation of the Director, Dr. Harlow Shapley.

On the evening of Friday, October 10, the Association was the guest of the Bond Astronomical Club, and a symposium on the methods of observing variable stars was presented. Mr. Leon Campbell described visual methods; Miss H. H. Swope dealt with photographic methods; Mrs. M. Mayall discussed the significance of spectral classes of variables; and Mrs. C. P. Gaposchkin summarized the situation by explaining the uses to which visual, photographic and spectral observations are put.

In the unavoidable absence of the President of the Association, Dr. Helen S. Hogg of the Dunlap Observatory, First Vice-President Dr. Dirk Brouwer, Director of the Yale Observatory, presided at the meetings. He was later elected President for 1942.

Mr. Leon Campbell, Recorder, presented his Tenth Annual Report. The annual number of observations has fallen to 38,043 because of war conditions, but the 30-year total of 850,000 is creeping towards the million mark.

Mr. Roy A. Seely, who was elected First Vice-President for 1942, reported that the Nova Search Committee has prepared a blueprint giving full instructions for searching for novae and showing the special search areas, which can be purchased by anyone interested from the Chart Curator of the A.A.V.S.O.

Mr. A. W. J. Cousins, Durban, South Africa, submitted a paper on the visual light curve of U Carinae. This cepheid was discovered in 1891 and has a period of about 38¾ days, but the evidence seems to point to a variation in the length of the period, which makes U Carinae one of the five known cepheids of this type.

Miss Marjorie Williams, Smith College, Northampton, Mass., reported that her study of the Scutum Cloud indicates that its nearer side is 1,600 parsecs distant and that it is 1,050 parsecs farther to the other side. The uncertainty as to the amount of interstellar light absorption renders any determination an approximation, and

these figures are based upon an absorption of one magnitude per kiloparsec.

Dr. C. W. Gartlein of Cornell University reported on the progress being made by the Cornell-National Geographic Society's study of aurorae. This program has been extended so that the work is to be carried on indefinitely. Observers in rural areas with a clear view to the northern horizon, especially those living north of the three active observing centres, Cornell and Colgate Universities in New York State and the city of Milwaukee, Wisconsin, are urgently needed. Slides illustrating the remarkable aurora of September 18, 1941, were shown. This occurred during an intense magnetic storm lasting about 48 hours. The aurora extended entirely across North America in longitude but only about 1,000 miles from north to south. It was clearly shown that an aurora is a three-dimensional phenomenon and that the same formation will appear quite differently from different viewpoints. For instance a corona over Poughkeepsie, N.Y., may appear only as a pencil of parallel rays rising from the horizon somewhat south of the east point from Toronto. This pencil of rays will point to the magnetic zenith above Poughkeepsie, some degrees south of the true zenith.

At the closing dinner on Saturday night Dr. Shapley listed some of the astronomical highlights of the year. The redetermination of the solar parallax by the Astronomer Royal, Dr. Spencer Jones, despite wartime conditions, as being 8″.7900 with an error of plus or minus 0″.0008, based upon observations made of the 1931 opposition of Eros was the first listed. Among others were the identification of iron lines, thirteen times ionized in the solar corona spectrum; the fact that the solar coronagraph at Climax, Col., has finally been able to record the corona, whereas former coronagraphs have apparently only shown the prominences; the discovery by Drs. C. Payne-Gaposchkin and Whipple that supernovae differ principally from novae by the greater speeds at which the matter expelled from them travel; the extension by Mr. Scott of Vanderbilt University of Dr. Martin Schwarzschild's theory of travelling waves of compression in cepheids to explain the light variations of long period variable stars; and the publication of a supplementary volume to the "History of Variable Stars" by Dr. Richard Prager.

SUN-SPOTS AND TREE RINGS

By Edwin Lincoln Moseley

WE have long known that trees derive their energy for growth from the sun, but not until recent years was the fact established that variations in the quantity and quality of solar radiation are taking place from day to day. Without such changes in the sun we would still have day and night, summer and winter, rain and sunshine—but would one year differ from another?

How our weather is affected by changes taking place on the sun is a complicated subject, imperfectly understood as yet. In this article will be found evidence that variations in the amount of rain falling in Ohio and states near it are influenced by solar variations.

Each year a tree adds new wood just inside the bark. The wood formed in a single year constitutes a ring. In the Northern States I have never found a hardwood tree of any kind that failed to form a ring every year as long as it lived, or one that formed two rings in one year. Knowing when a tree was cut down we can date every ring by beginning at the outside of the wood in the stump or log and counting toward the centre. If the tree was felled last fall or winter, then the ring next to the bark was formed in the growing season of 1940; the ring next to it in 1939, and so on. If the tree was old enough, we can find the ring that formed in 1776 or 1607. We must be careful not to overlook rings that are very narrow and not to mistake for two rings what is really only one.

A wide ring means rapid growth, a narrow ring slow growth. The width of a ring depends on many things—the kind of tree, its age at the time the ring was formed, the amount of moisture in the soil, the temperature of soil and air, the amount of light that reaches the tree, and injury by insects, rodents, fungi, lightning, fire or the falling against it of a large tree that was standing near it.

Competition with surrounding trees and with other vegetation has a marked effect on the growth of a tree, for its near neighbours take much moisture and light which otherwise it would absorb.

In the Southwest, where trees are far apart and the ground dry much of the time, the amount of rain that falls and penetrates into the soil is of the utmost importance. In the Eastern States, where rains are more frequent, competition with other trees may be quite as important.

If we find on a certain stump that the ring which was formed in 1895 is narrow we cannot be sure from this observation alone that 1895 was a dry year, for other things may have retarded the growth of this tree at that time. If we examine several other stumps in the same woods and in all of them find that the 1895 ring was narrower than that of 1896, we conclude that there was probably less rain in the growing season of 1895 than in the following year. I well remember that the summers of both 1894 and 1895 were dry and that in 1896 vegetation of all sorts made a luxuriant growth. This is recorded by the tree rings, not only in one woods but in all the woods in Ohio and the adjacent states wherever I have examined the stumps. It does not apply, however, to all parts of the country. In northeastern Louisiana I examined thirteen oak stumps all of which had a narrow ring formed in the year 1894. The 1895 ring was wide in two of them but in the rest it was neither narrow nor wide. The 1896 ring in six of the stumps was very narrow, in four others it was narrow, in none was it wide. My host in Louisiana at that time, had been there all his life. In 1896 crops suffered from drought more than in any other year which he could remember. Evidently the storm tracks that brought heavy rain in the spring and summer of 1896 crossed the country farther north than Louisiana.

As far back as the weather records go they correspond to the tree rings. However, rain falling after September has little or no effect on the growth of deciduous trees the same year, so that the total rainfall of a certain year may be above average, while the tree ring formed that year is not so wide as the average, but this is not usually the case. Tree growth is most affected by the rainfall from April to August. Rain or snow earlier in the year, or even in the preceding year, may have considerable effect, depending largely on the slope of the land, depth and character of the soil and whether the ground is frozen at the time the snow melts.

The U.S. Weather Bureau has published records of monthly

rainfall, not only since 1870, when Congress first made provision for meteorological observations, but also such data as were available for earlier years. West of Pennsylvania and New York State there are only a few places whose rainfall record antedates the middle of the nineteenth century. In many of the states there is not a single station where rainfall records were kept continuously for many years before that. For information about precipitation in earlier years we must look to the tree rings.

Each "tree ring number" in this article shows the percentage of all the trees studied in the area which made a ring that was clearly wider than the average; or, if negative, narrower than the average. If all were wide, the number for that year would be 100; if all were narrow, −100. Except in small areas or those represented by a small number of trees, one or more of the trees is likely to have a ring that is not obviously narrow, although the season was dry enough to cause a narrow ring to be formed in all of the others. This may be due to these few trees having been favoured by local showers or by exceptionally good environment. As an example, take the year 1930, which readers can recall. Of 19 trees in southern Kentucky and northern Tennessee whose rings I have studied, I recorded 13 as showing narrow rings, 2 rather narrow (each counting one-half) one very narrow (counting two). This gives a total of 16 for 19 trees, or 84 per cent of the whole number studied; so the number for that year is −84.

Numbers lower than −100 (like some of those for 1839, which was 91 years before 1930) are due to the large number of very narrow rings, each of which counts double.

The curves of tree growth in this article are based on tree ring numbers derived in this way. Graph II is for years so recent that readers can recall some of the outstanding wet and dry years and compare their recollection of them with their position in the curve.

Do tree ring widths show any correlation in time with changes on the sun's surface? The things most plainly visible on the face of the sun are the spots, which are sometimes large enough to be seen without a telescope. They change so frequently and irregularly that not until long after the first use of the telescope for viewing heavenly bodies did anyone discover any rhythm in their occurrence. Although the spots are not so hot as the rest

of the sun's disc, yet their presence in greater size and number than usual goes with greater intensity of solar radiation. It is the latter and not the spots themselves that account for our weather. The spots are sometimes absent for a year or more and yet vegetation on the earth continues to grow. Moreover, the number of spots that are visible from the earth is affected by the planet Venus, and probably also by Mercury. Electric repulsion by Venus and by the earth probably accounts for the fact that fewer spots are visible when the two planets are on the same side of the sun than when they are in opposite directions from the sun. In the former position both planets are driving some of the spots to a part of the sun that is turned away from us.*

The sun-spots may be no more dependable as indicators of solar radiation than tree rings are of terrestrial precipitation. Bearing this in mind, it is remarkable that we find so good a correlation as we do between sun-spots and tree rings.

1st. Let us consider those times when sun-spots were large and numerous and those when few, if any, could be seen. There have been 17 sun-spot minima since the middle of the 18th century, when the continuous record began. In the region extending from southern Michigan to northern Tennesee I found that most of the tree rings which were formed at the times of sun-spot minima were narrow. A few minima appear to be exceptions to this rule. They may be explained as follows: 1775 was a wet year, as shown by the wide tree rings, and yet it was a year of minimum sun-spots. The year 1774 was very dry; in August of that year the sun-spot number was 6.6, which was lower than in any month for nearly nine years before and lower than the average in 1775. The year 1821 was very dry; it was the first of four consecutive years in which there were months free from spots. The following year, 1822, was rather wet and 1823 was wet, although as a whole it had fewest spots. At the minimum, 1878-79, each year had only one month free from spots. Precipitation was not far from normal but was distinctly less than in the years 1876-77 and 1880-84. The year 1833 as a whole had fewer spots than 1834, but not in the first

*Fernando Sanford, "Influence of Planetary Configurations upon the Frequency of Visible Sun Spots." *Smithsonian Miscellaneous Publications*, 3391, 1936.

half of the year. A majority of the trees made a good growth in 1833 but not in 1834.

Recently I have compared my tables of wide and narrow tree rings with sun-spot numbers earlier than 1749. Although the dates assigned for the early minima are uncertain, I find that a majority of them were times when rainfall was below normal, several of them when it was much below. Examples of these quite dry minima are: 1610-11, 1619-21, 1679-80, 1698-99, 1712, 1724, 1734.

In the period 1808-12, the sun showed fewer spots than in any equal period since. From October 1809 to June 1811, no spots were visible. A large part of the stumps show narrow rings, 1808-12; very few show a wide ring for any of those years. Ninety years later, in 1901, the number of spots in the twelve months averaged only 2.7; with one exception, this is the smallest yearly average in the past 117 years. In 1901 nearly all of the trees formed a narrow ring. Old farmers remember what poor crops they had that year.

2nd. After every sun-spot maximum from 1704 to 1937 there was a decline in the amount of precipitation.

If years alone are considered, there is an exception to this rule in the maximum of 1905 (spots 63.5) followed by 1906 (spots 53.8) and 1907 (62.0), but the highest monthly maximum was in February, 1907 (spots 108.2). The months following that, March to July, which are the ones that have most effect on tree growth, had fewer spots in 1907 than these months in 1906. The decline in tree growth occurred between 1906 and 1907.

At a majority of the maxima the decline in precipitation occurred as soon as the sun-spot number became less; in other words, the succeeding year was less wet than the year which had the highest sun-spot number. The only exceptions are found where the succeeding year had nearly as many spots as the year of maximum, the decline in rainfall occurring when there was a decided fall in sun-spot numbers.

In six instances there was a noticeable decline in precipitation both in the year following the maximum and in the year after that. This applies to the years 1750-52, 1817-19, 1837-39, 1884-86, 1893-95, 1928-30.

Of the four years preceding the sun-spot minimum at least half

usually have less than the normal amount of rain. Some of them may be as dry or even drier than the year of sun-spot minimum. The fourth year before the year of minimum sun-spots has usually had much less than normal precipitation. This is true of all minima since that of 1901 and all in the 18th century prior to 1799. It is not true of the minima of 1867 or 1888. The year 1829, four years before the minimum of 1833-34, had nearly normal precipitation, although all of the other years between 1825 and 1830 had more than normal.

3rd. Soon after the minimum, beginning sometimes while sun-spot numbers are still low, precipitation is usually well above normal and it usually continues to be above or near normal most of the time until the following maximum. Sometimes, as in 1845 and 1936, there is a sharp but brief drop in the tree ring curve not long after the minimum. Table 2 and the graphs illustrate this.

It follows from the preceding rules that more rain usually falls between the sun-spot minimum and the following maximum than between the maximum and the following minimum, allowance being made for difference in length of these intervals.

4th. When the years from 1749 to 1940 are distributed into quarters according to their sun-spot numbers, as in table 1, we find that the quarter having the small numbers (0-14.5) had more dry years and fewer wet ones than any of the other quarters. It contains ten very dry years, or as many as the other three quarters together. Seven of these ten had lower sun-spot numbers than the average of the 48 years in this quarter.

TABLE 1

No. of Years	Annual Sun-spot Numbers	Very Wet	Wet	Rather Wet	About Normal	Rather Dry	Dry	Very Dry
48	0 to 14.5	3	9	4	7	7	8	10
48	15 to 40	4	10	7	5	5	13	4
48	41.1 to 65	12	10	5	6	6	5	4
48	over 65	10	7	8	5	8	8	2
15	over 100	4	2	2	–	2	4	1

5th. Years with large sun-spot numbers do not, on an average, have more rain than years when spottedness is considerably less.

Table 1 shows that the 48 years whose numbers exceed 65 had less rain than those 48 years whose numbers range from 41.1 to 65, and the 15 years that were highest in sun-spots (101.7-154.4) had no more annual rain than the 33 with spots between 65 and 100.

The second quarter, 48 years with spots ranging from 15 to 40, was intermediate in wetness between the first quarter (spots 0-14.5) and the third quarter (spots 41.1-65).

6th. When we compare two successive long periods whose relative wetness is known, we find that the one in which there was more rain had the higher average sun-spot number.

Tree rings show that the 45-year period, 1801-1845, had less rain than either the preceding or the following period of the same length, also that in 1846-1890 there was more rain than in 1891-1935. The latter is confirmed by weather records as far as the records go.

Thus there were alternating wet and dry periods of 45 years each. In these four periods the average sun-spot numbers were as follows:

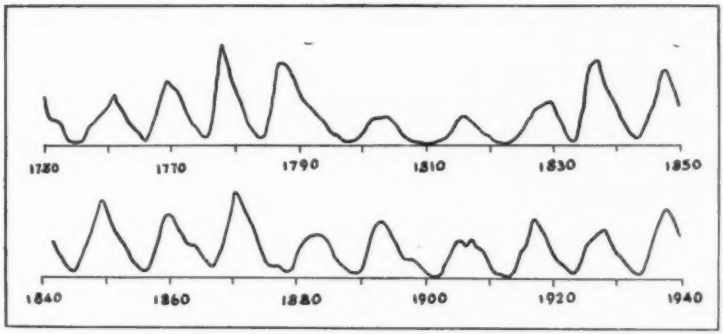
1756-1800, which had the most rain of all, 55.1
1846-1890, wet..... 46.5
1801-1845, driest of all..... 35.6
1891-1935, dry..... 38.3

	No. of years	*Wet*	*Dry*	*Sun-spot numbers*
1695-1707...	13	6	3	little known.
1708-1728...	21	1	17	most of them low.
1786-1796...	11	11	0	over 64 in six of the eleven years.
1799-1821...	23	5	16	none exceeding 47.5.
1875-1886...	12	11	0	over 50 in 42% of the years.
1887-1914...	28	7	18	over 50 in 25% of the years.

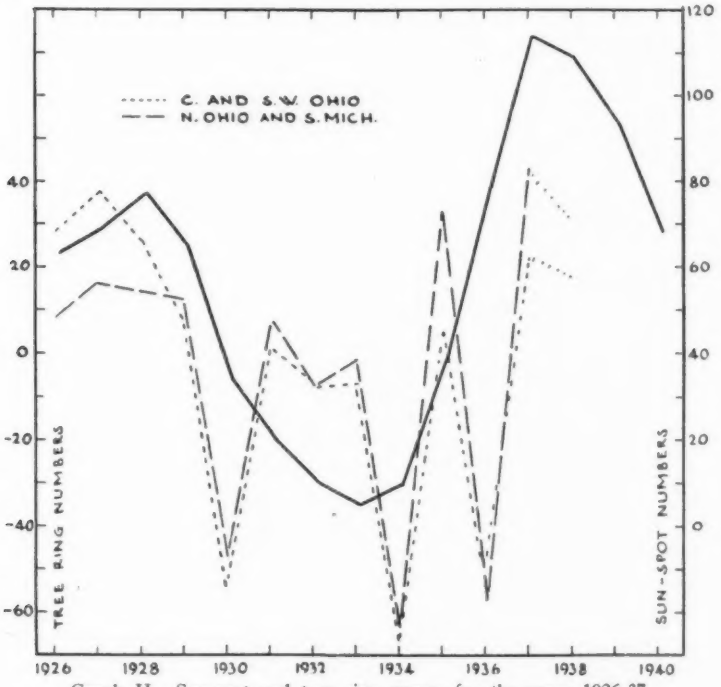
For shorter periods whose growth rate I have measured, rule 6 applies, with one exception.

7th. After eight periods, averaging about 11.3 years each, the sun-spot curve repeats. See graph I. This is true also of the tree ring curves as shown by graphs III and IV.

If the rate of tree growth depended on a solar cycle of exactly ninety years, then after the lapse of that time we would expect the growth rate to be again just as it was at the beginning. If the cycle is about $90\frac{1}{2}$ years the effect would be somewhat different, for its maximum influence would come at a different season of the



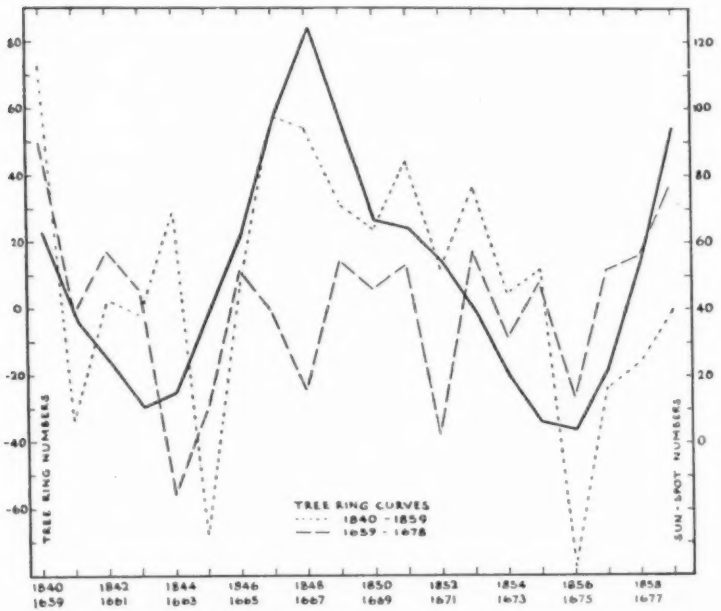
Graph I.—The sun-spot curve repeats after about 90 years.



Graph II.—Sun-spot and tree ring curves for the years 1926-37. Weather records for the growing season of 1927 show much more rain in central and south-western Ohio than in the northern part of the state.

year. It might affect rainfall sometimes ninety-one years later more than that ninety years later; at other times this might be reversed. (See table 2.)

After 181 years the effect would come more nearly at the same season. My curves, only part of which are shown here, seem to favour this view (see graphs III and IV). Elsewhere I have shown

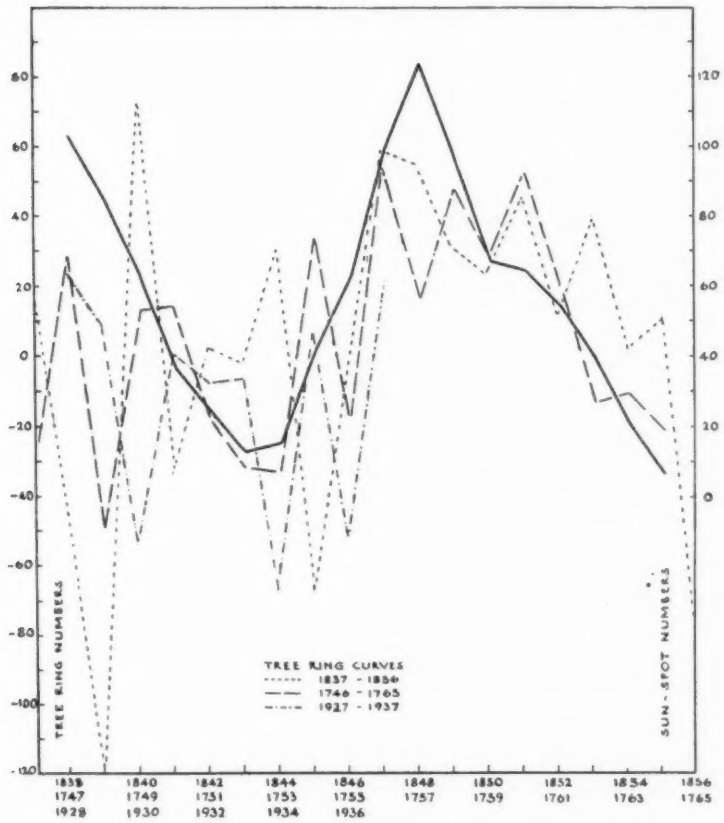


Graph III.—Repetition of tree ring curve after an interval of 181 years.

evidence of a tree ring cycle of about 90.4 years. See "The Ninety-year Precipitation Cycle," *Michigan Academy of Science, Arts, and Letters*, Vol. XXV, 1939, Reprint; also, "Long Time Forecasts of Ohio River Floods," *The Ohio Journal of Science*, Vol. XXXIX, No. 4, July 1939, Reprint.

The year 1816 had a very unusual summer. It was not only dry, according to a diary kept at that time, but was also so cold

that crops were a failure. On May 30, there was frost as far south as Virginia. In Massachusetts and the interior of New York State there was a 7-inch snowfall in June. In some states snow is said



Graph IV.—Tree ring curves with intervals of 90, 91 and 181 years.

to have fallen every month in the year. On August 30, snow fell in England within thirty miles of London. There, as in America, 1816 was "The year without a summer."

TABLE 2—Tree Ring Numbers in Various Areas

	6 counties in 3 states, all near the northwest corner of Ohio.		Fulton County, Ohio, adjacent to some counties in the first group.		Wood, Lucas, Seneca and Wyandot, all farther East in Northern Ohio.		Marion, Logan, Anglaize, Licking, Central Ohio.		5 counties in Southwestern Ohio.		Northern Tennessee and the adjacent part of Kentucky.		West Carroll Parish, near the northeast corner of Louisiana.		Southern Michigan and Northern Ohio, average of 1st 3 groups.		Central and Southwestern Ohio, average of 2 groups.	
No. of trees . . .	*15*	*20*	*19*	*28*	*38*	*34*	*26*	*32*	*24*	*26*	*19*	*15*	*13*	*13*	*72*	*82*	*50*	*58*
Years																		
1847		25		62		41		53		62		13		50		43		58
1937	45		*x*		40		15		27		*x*		*x*		43		21	
1846		−25		− 2		9		−14		29		27		12		− 6		8
1936	−75		*x*		−40		−37		−65		−71		−58		−58		−51	
1845		−78		−66		−68		−73		−65		0		−15		−71		−69
1935	40		*x*		25		8		4		5		23		33		6	
1844		23		27		41		44		15		−23		12		30		30
1934	−80		−45		−70		−56		−77		−21		8		−65		−67	
1843		−23		12		−13		−20		15		3		4		− 8		− 3
1933	0		0		− 4		− 8		− 6		−16		42		− 1		− 7	
1842		5		− 5		4		0		4		0		38		1		2
1932	−20		2		− 4		−17		2		− 5		−69		− 7		− 8	
1841		−35		−12		− 3		−19		−50		−20		−15		−17		−35
1931	10		24		−12		−10		12		−11		0		7		1	
1840		63		36		0		72		73		−20		−15		33		73
1930	−43		−47		−56		−37		−71		−84		−54		−49		−54	
1839		−180		−134		−80		−90		−158		−67		−38		−131		−124
1929	−13		50		0		− 7		25		26		38		12		9	
1838		−20		−45		−21		−39		−48		33		−23		−29		−44
1928	19		9		13		35		19		26		46		14		27	
1837		23		− 2		21		− 3		34		33		35		14		16
1927	19		9		21		43		33		16		96*		16		38	
1836		43		48		50		20		4		47		15		47		12

This arrangements of tree ring numbers makes it possible to compare those of recent date with those 90 years earlier and also with those 91 years earlier.

In 1839 the trees grew less than in any other year of the nineteenth century.

x—Few or no rings in the tree ring record. *This very high positive number for the 1927 ring in Louisiana is for the year of the great flood in the Mississippi River.

TABLE 3

SOME YEARS WHEN TREES GREW VERY LITTLE

Number of trees studied	Date of tree ring	Tree ring number	Number of trees studied	Date of tree ring	Tree ring number	Number of trees studied	Date of tree ring	Tree ring number	Number of trees studied	Date of tree ring	Tree ring number	Number of trees studied	Date of tree ring	Tree ring number	Number of trees studied	Date of tree ring	Tree ring number
			159	1895	− 80	144	1804	−24	97	1714	−18	31	1623	−42	4	1533	− 50
			161	1867	− 58	133	1777	−11	69	1687	−42	17	1596	−32	2	1506	−150
			155	1856	− 75	131	1766	−10	64	1675	−40	15	1584	−83	2	1494	−200
142	1936	−58	155	1845	− 56	130	1755	−27	56	1664	−42	11	1574	+ 9	2	1483	−150
142	1930	−58	155	1839	−119	126	1748	−51	43	1658	−12	8	1568	−44			
148	1911	−68	145	1821	− 50	103	1730	−11	40	1640	−25	5	1549	−90			
148	1907	−12	144	1816	− 91	102	1726	− 5	31	1636	−12	5	1545	−20			

In the column headed by 1895 are the dates of the seven poorest years for tree growth in the 19th century. In general, years whose weather is unfavourable for growth are followed after an interval of 90 or 91 years by similar weather. The year 1816 at the bottom of the column, unlike those above, is the only one in its series (horizontal line) that shows *very* poor tree growth. For the explanation see text, p. 392.

The data for this table were obtained from stumps in Ohio, Michigan, Tennessee and Kentucky. The tree ring number for each year for northern Ohio and adjacent part of Michigan and that for central and southwestern Ohio were added, their sum was doubled and added to the number for Tennessee and adjacent Kentucky, then this sum was divided by five. The number of trees representing the southern area is much smaller than in the other areas; prior to 1714 it is so small that it was not used.

The trees grew less in 1816 than in any other year of the 19th century except 1839. In Louisiana they were not so seriously affected by the cold as farther north. In Connecticut, not far from Long Island Sound, a majority of them formed rather wide rings in 1816.

Most of the years when many trees formed very narrow rings were preceded by one or more years when rain was less than normal so that the water-table was low when the growing season began, but

x—Few or no rings in the tree ring record. This very high positive number for the 1927 ring in Louisiana is for the year of the great flood in the Mississippi River.

TABLE 4

TREE RING NUMBERS

	Sunspots	Northern Ohio, Southern Mich.	Central and Southwestern Ohio.				Sunspots	Northern Ohio, Southern Mich.	Central and Southwestern Ohio.	Tennessee and adjacent Kentucky.	Northeastern Louisiana.
No. of trees →		*44*	*30*			*No. of trees*		*57*	*41*	*7*	*7*
1698	low	−18	−62			1728		0	− 5	0	57
1699	low	−40	−87			1729		− 3	29	29	57
1700	low	−31	−75			1730		− 8	2	−43	−36
1701	low	−10	−32			1731		− 1	− 5	−43	13
1702	low	− 2	− 2			1732		34	20	−21	31
1703		16	38			1733		−21	1	29	0
1704		25	36			1734	min.	−63	−20	− 6	−50
1705	max.	− 5	46			1735		−31	−16	−62	0
1706		− 3	23			1736		16	−46	−50	−22
1707		7	16			1737		56	−48	−25	28
1708		−26	− 6			1738	max.	−28	11	0	33
1709		−58	−17			1739		−46	−10	19	0
1710		−40	7			1740		−16	16	0	−22
1711		−23	−25			1741		6	28	0	−15
1712	min.	−44	−15			1742		−42	−14	37	−45
1713		−33	− 2			1743		−63	−61	−81	15
1714		−39	−12			1744		12	−51	12	−45
1715		−21	−18			1745		18	9	0	15
1716		−41	5			1746	min.	− 5	−26	−50	10
1717	max.	−21	20			1747		35	28	25	40
1718		−17	−37			1748		−50	−56	−44	−25
1719		11	−16			1749		− 7	10	−87	−20
1720		−20	−58			1750	max.	7	12	−25	−14
1721		−15	−44			1751		− 9	−19	−56	0
1722		−18	−39			1752		−27	−33	−37	14
1723		−36	−33			1753		−15	−35	−55	63
1724	min.	−83	−72			1754		16	31	20	− 8
1725		50	30			1755	min.	3	−20	−100	−25
1726		9	0			1756		53	59	15	−25
1727	max.	− 4	12			1757		17	14	− 5	−63

TABLE 4—*Cont.*

TREE RING NUMBERS

	Sunspots	Northern Ohio, Southern Mich.	Central and Southwestern Ohio.	Tennessee and adjacent Kentucky.	Northeastern Louisiana.		Sunspots	Northern Ohio, Southern Mich.	Central and Southwestern Ohio.	Tennessee and adjacent Kentucky.	Northeastern Louisiana.
No. of trees →		*67*	*49*	*10*	*12*	*No. of trees*		*68*	*55*	*10*	*13*
1758		58	46	90	−50	1788	high	42	47	45	19
1759		29	23	30	13	1789	high	46	41	55	23
1760		39	50	55	4	1790		23	28	− 8	19
1761	max.	12	21	18	38	1791		26	13	36	8
1762		− 4	−15	−20	29	1792		1	23	4	12
1763		27	−13	− 5	63	1793		45	39	84	− 8
1764		−56	−23	5	38	1794		37	50	74	4
1765		−15	− 2	−10	−58	1795		27	12	58	−23
1766	min.	24	−16	−64	−17	1796		12	40	20	15
1767		−14	−32	−73	−113	1797	low	−20	17	30	65
1768		36	68	30	−67	1798	low	11	1	20	8
1769	max.	17	17	10	−17	1799	low	−31	−39	−38	−54
1770		−45	−67	−25	13	1800	low	−69	−66	−10	−104
1771		−13	−71	0	16	1801		−19	−17	0	−77
1772		− 3	−18	−20	−16	1802		−17	−29	0	−73
1773		15	9	10	−23	1803		−54	−23	−27	−62
1774	*min.	−27	−84	−60	−20	1804	max.	−11	−23	−53	−81
1775		24	23	−15	31	1805	high	16	12	−13	31
1776		− 8	29	35	20	1806		−17	−42	0	−81
1777		15	−25	−35	−20	1807		22	4	−20	4
1778	max.	−14	−19	−10	8	1808	low	−38	−43	23	4
1779	high	−16	2	20	38	1809	low	−27	−26	−10	−12
1780		−36	−76	0	−35	1810	min.	−36	−47	−27	27
1781		7	9	−10	−12	1811	low	−38	−22	−27	− 8
1782		−17	− 2	30	−15	1812	low	− 7	−13	−33	−15
1783		−17	−36	10	−12	1813		− 1	33	−47	62
1784	min.	−20	−69	−50	−58	1814		40	56	33	−23
1785	low	−43	−30	−70	−15	1815		21	29	23	31
1786		17	41	60	−46	1816		−84	−114	−60	−35
1787	max.	45	56	80	4	1817	max.	− 8	31	13	−46

*See text, page 379

TABLE 4—*Cont.*

TREE RING NUMBERS

	Sunspots	Northern Ohio, Southern Mich.	Central and Southwestern Ohio.	Tennessee and adjacent Kentucky.	Northeastern Louisiana.		Sunspots	Northern Ohio, Southern Mich.	Central and Southwestern Ohio.	Tennessee and adjacent Kentucky.	Northeastern Louisiana.
No. of trees →		*72*	*58*	*15*	*13*	*No. of trees*		*82*	*58*	*15*	*13*
1818		−19	− 9	20	−46	1848	max.	79	54	0	−12
1819		−16	−34	−33	−54	1849		15	30	40	46
1820		−59	−34	40	15	1850		37	22	27	− 8
1821	*min.	−46	−58	−40	−77	1851		37	46	20	− 8
1822		26	− 5	17	23	1852		−12	10	33	−31
1823		24	51	7	12	1853		5	40	−10	19
1824		6	19	13	−38	1854		− 1	3	13	8
1825		−19	−19	−57	− 8	1855		48	11	−13	−123
1826		24	− 3	20	31	1856	min.	−67	−78	−83	50
1827		23	53	33	−15	1857		−10	−23	−20	−62
1828		45	58	47	0	1858		−19	−15	10	12
1829		− 9	5	23	12	1859		− 4	2	−10	−50
1830	max.	26	55	17	−12	1860	max.	− 9	17	0	−56
1831		31	3	17	− 8	1861		−25	5	0	19
1832		25	9	0	19	1862		36	44	20	19
1833	low	30	14	−33	4	1863		25	11	13	4
1834	low	9	−11	− 7	8	1864		− 6	− 9	−17	4
1835		10	15	−17	−12	1865		13	− 5	−17	50
1836		47	12	47	15	1866		31	25	− 7	4
1837	max.	14	16	33	35	1867	min.	−59	−70	−30	−27
1838		−29	−44	33	−23	1868		−16	−12	−13	−38
1839		−131	−124	−67	−38	1869		55	54	13	−50
1840		33	73	−20	− 8	1870	max.	−26	−53	−10	12
1841		−17	−35	−20	−15	1871		−34	−52	−27	− 4
1842		1	2	0	38	1872		−11	− 7	0	−19
1843	min.	− 8	− 3	3	4	1873		1	19	13	−15
1844		30	30	−23	12	1874		−18	−22	−20	−88
1845		−71	−69	0	−15	1875		− 1	28	27	35
1846		− 6	8	27	12	1876		54	34	87	−27
1847		43	58	13	50	1877		44	32	13	23

*See text, page 379

TABLE 4—*Cont.*

TREE RING NUMBERS

	Sunspots	Northern Ohio, Southern Mich.	Central and Southwestern Ohio.	Tennessee and adjacent Kentucky.	Northeastern Louisiana.		Sunspots	Northern Ohio, Southern Mich.	Central and Southwestern Ohio.	Tennessee and adjacent Kentucky.	Northeastern Louisiana.
No. of trees →		*86*	*58*	*15*	*13*	*No. of trees*		*77*	*52*	*19*	*13*
1878	min.	55	50	− 7	27	1908		10	− 5	5	23
1879	low	47	6	0	50	1909		−12	−24	16	−23
1880		63	34	40	0	1910		−68	−59	− 3	38
1881		67	22	60	−77	1911	low	−44	−86	−79	−23
1882		65	39	67	69	1912	low	18	49	11	50
1883	max.	63	59	80	58	1913	low	−19	− 6	−34	12
1884	high	47	17	60	38	1914	low	−76	−66	−84	−123
1885		15	26	10	− 8	1915		39	68	21	85
1886		− 5	9	27	−12	1916		44	43	32	69
1887		0	−18	−13	−15	1917	max.	14	11	− 5	−19
1888	low	−10	−19	−20	15	1918		−38	−56	−16	−12
1889	low	22	43	7	31	1919		−41	−46	−32	−31
1890	low	−26	−28	− 7	0	1920		8	5	− 5	31
1891		−19	− 2	−13	− 8	1921		5	2	−11	31
1892		15	31	13	50	1922		33	36	21	−27
1893	max.	− 7	0	7	54	1923	min.	5	0	24	38
1894		−28	−42	−93	−96	1924		5	16	5	− 4
1895		−89	−67	−87	15	1925		−65	−61	−111	−96
1896		64	47	− 7	−127	1926		8	29	− 5	54
1897		4	36	0	−19	1927		16	38	16	96
1898		4	− 3	−20	−38	1928	max.	14	27	26	46
1899		7	7	− 7	−27	1929		12	9	26	38
1900		13	−32	−16	−35	1930		−49	−54	−84	−54
1901	min.	−56	−40	−16	−23	1931		7	1	−11	0
1902		45	35	−16	−38	1932		− 7	− 8	− 5	−69
1903		39	31	0	31	1933		− 1	− 7	−16	42
1904		−13	5	−16	15	1934	min.	−65	−67	−21	8
1905	high	−16	22	−11	− 4	1935		33	6	5	23
1906	*high	7	− 1	− 5	−62	1936		−58	−51	−74	−54
1907		−15	−15	0	38	1937	max.	43	21		

*See text, page 380

the curve for 1816 drops abruptly from +21 to −84 (S. Michigan and N. Ohio), and from +29 to −114 (Central and S.W. Ohio). The years 1814 and 1815 had more rain than any other two consecutive years in the 19th century prior to 1823.

This anomalous behaviour of the weather in 1816 was not caused by anything unusual taking place in the sun; it was due to a terrific eruption in 1815 of Tomboro, Sumbawa Island, East Indies, which killed 12,000 people and ejected lava estimated to have been enough to make six cubic miles. It was the fine dust from this volcano, carried in the upper air currents around the world, that affected the weather in 1816. No wonder the curve of tree ring numbers ninety or ninety-one years later or earlier fails to follow the curve for 1816. (See table 3.)

University Museum,
Bowling Green, Ohio.

REVIEW OF PUBLICATIONS

Between the Planets, by Fletcher G. Watson. 222 pages, 5½ x 8½ ins., with 106 illustrations. Philadelphia, The Blakiston Co., 1941. Price, $2.50

This is one of a series of nine volumes covering the entire field of astronomy, written by members of the staff of Harvard Observatory. The present book deals with asteroids, comets, meteors and meteorites. It is intended for the intelligent layman and the amateur astronomer, as would be suggested by the titles of its ten chapters: Surveying the solar system; The little planets; Whirling fragments; Comets in motion; Anatomy of a comet; Shooting stars; Meteor showers; A meteorite falls; Meteorites in the laboratory; Betwixt and between.

Spread over its pages are numerous diagrams and half-tone illustrations, few of which have been seen in previous elementary texts on astronomy. The present reviewer thinks the inscriptions to the cuts are generally too brief and consequently the average reader will have difficulty in appreciating the significance of some of the diagrams. Further, he usually likes to know the circumstances under which the photographs—some quite unique—were taken, including the date and place.

In the history of the three classes of celestial objects discussed in the book there are many picturesque details and remarkable facts. Also the results of observation are multitudinous and complex. Only a person of great ability and fertility of imagination can make critical judgments of the various theories put forward to account for the observed facts; as for instance, the domination of Jupiter over certain asteroids and comets, or the determination of the velocities of meteors and their relation to the solar system. The author handles such matters with clearness and decision.

The last sixty per cent. of the book is devoted to meteors and meteorites. In no other single place can one find the information which the author has collected, systematized and presented here in simple form. There is an abundance of late news and views. The treatment of meteor craters is especially full and interesting.

The author attempts to satisfy the desire of the ordinary reader to learn the origin of the various heavenly bodies. As to the asteroids he says: "Unless there is a reason to believe otherwise, we can proceed on the hypothesis that all the asteroids came from the parent body, which did not exceed the earth in size."

After giving several hypotheses and speculations which have been proposed to explain where the comets come from, the author wisely remarks: "Perhaps we should be very honest and say that we do not know how, when or where comets were formed."

With respect to meteorites: "Our astronomical knowledge proves their extraterritorial origin, but is not definite regarding their permanent membership in the solar system. . . . In the past a great variety of origins have been assigned to meteorites, even volcanic action on the moon. We must, however, place their origin much farther from the earth. . . . They may have grown in space through the accumulation of individual atoms, . . . through the accumulation of small bits of solid material, or they may be fragments of some solid body comparable to a planet."

Our search for origins is not very satisfying! C. A. C.

The Milky Way, by Bart. J. Bok and Priscilla F. Bok. Pp. 204, 8½ by 6 in. Philadelphia, The Blakiston Co., 1941. Price $2.50.

This beautiful little volume, listed as the next to the last in the Harvard series of nine volumes on various fields of astronomy, is actually one of the first to appear. The authors have written on one of the most complex subjects of modern astronomy, but in such a way that the book is complete in itself and presupposes a minimum of astronomical knowledge.

The style will prove very easy reading for the general reader. The illustrations are excellent, both of star fields, and of photographs of modern astronomers. To an amateur reader, the usefulness of Table I is somewhat hampered by a misplaced minus sign in the column of visual magnitudes.

The concluding chapters of the book are especially fine in their description of our galaxy, and in impressing the reader with the vast stretches of time involved in cosmic years, where a cosmic year is about 200 million of our years, or the length of time it takes

the sun to revolve once around the centre of the galaxy. The book reaches a good climax at the point where the authors say "As small a change in the sun's total brightness as one magnitude would automatically result in a change of the average temperature of the earth by seventy-five degrees centigrade. . . . It is improbable that life at the surface of the earth could adjust itself to an average temperature around the boiling point of water, or to conditions prevailing at fifty degrees centigrade below zero."

The amateur astronomer will find the book ideal reading. The professional astronomer may wish that in a book in such an extensive and expensive series there had been space for more specific information, details, and references. H. B. S. H.

The Fundamental Properties of the Galactic System. Annals of the New York Academy of Sciences, Vol. XLII, pp. 113-272.

This volume of the Annals of the New York Academy of Sciences contains the following eight papers read at a conference on the fundamental properties of the galactic system held at New York, May 2 and 3, 1941.

The Reference System of Stellar Positions, by H. R. Morgan.
The Reference System with a view to Planetary Dynamics, by Dirk Brouwer.
Mean Secular Parallaxes of Faint Stars, by Peter van de Kamp.
Mean Parallaxes from Peculiar Motions, by Emma T. R. Williams.
The Luminosity Function, by W. J. Luyten.
The Magnitude Scale Today, by Frederick H. Seares.
The Stellar Distribution in High and Intermediate Latitudes, by B. J. Bok and D. A. MacRae.
The Absorption Coefficient and the Luminosity Function in the Galactic Plane, by Jan Schilt.

The eight papers constitute almost a text on the galactic system. The first two papers especially are written in text-book style and cover the problem of reference systems for the positions, give the present status of the problem and suggest methods of procedure and observations for the future. The remaining papers are more along the lines of individual researches. Those dealing with the absorption of light in space are particularly interesting and we can hardly claim to know much about the fundamental properties of the galactic system until the question of absorption has been more completely answered. No discussion is included on the problems related to radial velocity.

R. K. Y.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Science and Faith

For centuries the relation between science and faith has been the subject of almost continuous discussion, often with bitter and unreasonable dogmatism on both sides. In the times of Copernicus and Galileo these great pioneers suffered severe persecution at the hands of men who did not or could not appreciate the discoveries they had made. During the latter part of the last century, in the present writer's boyhood, the warfare was waged with great vigour, the fighting being largely in the biological division of science. Much of this has been forgotten.

At the present time science dominates our outer material existence, but looking inward and considering those things which are not seen, we must agree that religious faith is a steadying and satisfying part of our lives. In these days of stress, when an attempt has been made in some countries to crush out all forms of religion, there has been a decided reaction towards spiritual values.

In March, 1941, Sir William Bragg, the distinguished British physicist, gave the Riddell Memorial Lecture, bearing the title at the head of this note, at the University of Durham; and in *Nature* for August 16 there is a review of the published lecture. Some quotations from the lecturer's words are given below.

> It seems to me that in recent years the way of the scientist and the way of the seeker for a good way of life have come to have more features in common than in the past, more than is generally recognized. If the scientist was ever unduly dogmatic he has ceased to be so: this one-time self-assertion at a time within living memory was in no small degree a weapon of offence and defence which he felt himself compelled to assume. In part it was a mistake of his own making. I should think that the theologian's dogma is now becoming more and more like the scientist's hypothesis, so probable of course that he accepts it and acts upon it always. If the theologian says I am not justified in my statement, I shall still suspect that the disagreement is subject to a misunderstanding.
>
> * * * *
>
> The whole knowledge at our disposal is far greater than modern science, as the whole is greater than the part. It includes the observations of countless

generations of men, their experiences of life and the record of their thoughts thereon and the comments of their interpreters and lawgivers, the histories of the actions of nations and individuals especially in relation to the faiths on which they have acted, all in fact that men have learnt since they first began to learn.

* * * *

. . . it is to be observed that all such [scientific] hypotheses are tentative and are to be amended constantly as knowledge grows. There is no finality in these attempts to draw conclusions. Some are more enduring than others, but it can never be said of any law formed and used by the scientist that it is good for all time.

Three outstanding examples cited by Sir William Bragg in illustration of the last paragraph are the atomic theory of matter, the Newtonian theory of gravitation and the wave theory of light. By many persons it was thought that they were absolutely and finally established, but in very recent years they have all been drastically revised—and yet they have been of great value in the advancement of science. They were not wrong, simply not complete.

ASTRONOMY

The science of Astronomie
I thinke farto specefie,
Withoute which, to telle plein,
Alle othre science is in vein
Toward the scole of erthli thinges;
For as an Egle with his winges
Fleth above alle that men finde,
So doth this science in his kinde.

—John Gower, "Confessio Amantis",
about 1390 A.D. Book VII, ll. 625-632.

C. A. C.

MEETINGS OF THE SOCIETY

AT TORONTO

October 7, 1941.—The Society met in the McLennan Physics Laboratory, University of Toronto, at 8.00 p.m., Dr. D. W. Best in the chair. Attendance was unusually large, being estimated at 125 persons.

Dr. Harold R. Kingston, Professor of Mathematics and Astronomy, and Director of the Cronyn Memorial Observatory, University of Western Ontario, London, addressed the meeting. He brought greetings from the London Centre of the Society, and spoke of the observatory, a memorial to the late Mr. Hume Cronyn, a business man who had taken keen interest in science. Essentially a student observatory, the building and its equipment was intended primarily for instruction, not for research, Dr. Kingston said. He expressed a hope, however, that some work of value in the field of astronomical research might be accomplished. "It helps immensely in our teaching activities and in popularizing astronomy," he said. "We are trying to make the gift fulfil the purpose for which it was presented to our university."

Speaking on "The Way of the Moon," Dr. Kingston pointed out that a study of the moon's motions in the sky could be a pleasant kind of "holiday astronomy" necessitating neither books nor charts. "They are not intricate motions that require the use of a telescope but are simple things that anyone can observe from the backyard or summer cottage," he said. "The fundamental idea is to get a mental picture of the position of the celestial equator for your latitude."

He first mentioned the moon's apparent motion from east to west; its rising and setting, due to the earth's rotation in the opposite direction. Second, he pointed out, there was the moon's real motion of revolution around the earth, easy to observe by comparing the moon's position relative to planets or bright stars at hourly intervals. This motion resulted in the moon moving eastward in the sky a distance about equal to its own diameter every hour, Dr. Kingston said. A complete revolution around the earth as determined by the stars takes 27 1/3 days. However, because the sun also has moved eastward during this interval, the result is a period of 29½ days from the time the moon is in conjunction with the sun, or in "new moon" phase, until it is new again.

Always within 5° 9′ of the ecliptic, the moon's path closely follows the sun's, the moon completing about 13 trips around the ecliptic each year. The *full* moon, Dr. Kingston explained, is always directly opposite the sun's position on the ecliptic, and hence, when the sun was low in the sky at noon, as in December, the *full* moon "rides high" at midnight. In summer, when the sun is high in the sky, the *full* moon 12 hours later will be closer to the southern horizon. The difference in altitude between summer and winter full moons

on the meridian is about 47°, or double the angular separation between the celestial equator and the ecliptic.

With the sun on or near the equator in April and September, the full moon occurring in those months would also be near the equator, Dr. Kingston said. Thus the *full* moon was always the same distance north or south of the equator as the sun but on the *opposite* side, i.e. when the sun is north of the equator, the full moon is south of it. New moon, being in or near conjunction with the sun, would be in the same position as the sun at any season of the year. The moon in "first quarter" phase, being on the ecliptic 90° east of the sun, would appear high in the sky in April and low in September, he added.

Whether the moon is "lying on its back so it will hold water," or is "tipped up on the lower horn so the water will spill out," the position had absolutely nothing to do with weather on the earth, Dr. Kingston went on. "All kinds of weather often exist at various places on the earth at the same time; hence the moon's influence on the weather seems to be a case of 'all things to all men,' or 'you pay your money and take your choice,'" he said. The ancient superstitions concerning "wet moons" and "dry moons" even seemed to contradict themselves, he added, since some amateur weather prophets called a particular new moon "wet" while others said it was "dry." The position of the horns depended entirely on whether the moon's location on the ecliptic was north or south of the equator, and at any station this position was relatively the same at the same season every year, Dr. Kingston said.

Dr. Helen S. Hogg gave the first talk in a series on "Explorations in Clusters and Nebulae," mentioning early references in astronomical literature to the so-called "lucid spots." As early as 300 B.C. Aratus mentioned Praesepe in his *Diosemeia*; Hipparchus referred to both Praesepe and the double cluster in Perseus in 129 B.C. Ptolemy in 137 A.D. referred to five "cloudy stars," and the Andromeda nebula was first recorded by Al-Sufi in 960 A.D., Dr. Hogg said.

With the early telescopes what previously had appeared as misty patches of light took on form and brightness, and astronomers realized that their hazy appearance was due not to faintness but rather to their enormous distances. Galileo resolved Praesepe into separate stars in 1610; two years later Simon Marius described the Andromeda nebula as "like a flame of candle shining at night through a transparent horn"; and Huygens first mentioned the Orion nebula in 1656.

Dr. Hogg went on to mention the various catalogues of clusters and nebulae, starting with Derham's catalogue of 22 objects published in 1733 in the *Philosophical Transactions* of the Royal Society; Lacaille's list of 42 objects in *Mémoires des Académie des Sciences* in 1755; Messier's catalogue of 103 objects published about 1781; Sir William Herschel's list of 1,000 published in the *Philosophical Transactions* in 1786, followed by a second and third list of 1,000 and 500 respectively in 1789 and 1802. Messier compiled his catalogue,

Dr. Hogg related, because the misty objects were continually getting into his way as he swept the sky in his search for comets.

Sir John Herschel published his *General Catalogue* of 5,079 nebulae and clusters in 1864, and this was followed in 1887 by Dreyer's *New General Catalogue* listing 7,840 objects which was published as one of the *Memoirs* of the Royal Astronomical Society. Two *Index Catalogues*, containing an additional 5,386 listings, were published by Dreyer in 1894 and 1908 respectively. With larger telescopes so many nebulae are being found that the cataloguing of them has become an endless job, Dr. Hogg said. "Ultimately the catalogues must run into millions of objects if the patience of astronomers will hold out that long," she said. In conclusion, she described some of the various types of nebulae and clusters.

Dr. Best announced that the four-inch telescope set up at the Canadian National Exhibition by the Society had proved a popular attraction and that a total of $70.05 had been turned over to the Red Cross British Bomb Victims' Fund, the proceeds of voluntary donations at the telescope.

Dr. Best told the members that a constellation study group had been proposed and that it would be organized if sufficient members desired, Miss Ruth J. Northcott having offered to give instruction.

Mr. H. G. Duncalfe presented a hand-made walnut gavel to the Society for the use of the chairman at meetings. The initials of the constellations of the zodiac were inset in brass letters around the head of the gavel.

FREDERIC L. TROYER, *Recording Secretary.*

FIRE-BALL OF OCTOBER 22, 1941: INFORMATION WANTED

On October 22, 1941, at 10.13 p.m., E.S.T., C. F. Fernald of Wilton, Maine, observed a very brilliant fire-ball which exploded with a brightness estimated at −10 magnitude and left a train which lasted 14 minutes. It disappeared over his western horizon and hence would be visible in Quebec east of Montreal. The director of the American Meteor Society is anxious for reports on this fire-ball. They should state the path of the body among the stars, together with notes or drawings of the drift of the train. Address: Professor Charles P. Olivier, Flower Observatory, Upper Darby, Pa.

C. A. C.

The Royal Astronomical Society of Canada

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